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Stopover ecology of Black-tailed Godwits *Limosa limosa limosa* in Portuguese rice fields: a guide on where to feed in winter

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Capsule Conservation management of rice fields may be necessary to guarantee the availability of high quality stopover habitats.

Aims To analyse habitat selection and quantify the diet composition of birds.

Methods Using water level and agricultural management of the fields as variables, habitat selection was analysed by compositional analysis. Godwit diet composition was quantified by faecal analysis, and food abundance was sampled to explain the observed habitat selection.

Results We found evidence of higher use of flooded and ploughed paddies than expected from their relative abundance. These fields have the highest densities of buried rice kernels, which seem to be the main food source for Black-tailed Godwits.

Conclusion Currently, godwits find good foraging areas in Portuguese rice fields, feeding primarily on rice kernels that are mostly found in flooded ploughed fields. Changes in rice farming, late ploughing and predicted decreases in rainfall may lead to loss of this habitat. However, because of the man-made nature of their requirements, it should be possible to install relevant land-use practices that guarantee the availability of high quality stopover habitats.

In the course of a long migration, birds need to stop a number of times for refuelling before continuing their journeys. The migratory journey is characterized by an alternation between flights, when distance is covered and energy is consumed, and stopover periods, when energy for the next flight stage is accumulated (Gudmundsson *et al.* 1991, Alerstam & Hedenström 1998). Most of the time and energy expenditure during an entire migration episode is actually spent on the ground (Hedenström & Alerstam 1997). Migratory stopovers are very important periods in the yearly cycle of migrant birds, with downstream consequences for survival, breeding success and demographics (Newton 2006). As a consequence, knowledge of habitat requirements of migrants during stopover is crucial for their conservation (Piersma & Baker 2000, Chernetsov 2006). Despite this, stopover ecology has remained one of the least studied aspects of avian migration (Lindström 1995).

Black-tailed Godwits *Limosa limosa* are long-lived

migratory birds. The continental European race *L. limosa limosa* mostly breeds in agricultural grasslands in northern and eastern Europe, where it faces a serious population decline (Birdlife International 2004), leading to the recent classification of the species as 'Near Threatened' on the IUCN Red List (IUCN 2007). Although this decline is mostly blamed on habitat loss and changes in agricultural practices in the breeding areas (Beintema *et al.* 1985, Beintema & Müskens 1987), the failure of most conservation programmes (Kleijn *et al.* 2001, Kleijn & Van Zuijlen 2004) suggests that this subspecies could be facing additional problems at other times during its annual cycle. Black-tailed Godwits winter in west Africa in marshes, flooded plains and rice fields (Cramp & Simmons 1983) and an important part of this population performs an extended stopover in the Iberian Peninsula, during the prenuptial migration, where they mostly use rice fields as foraging habitat (Beintema *et al.* 1995, Kuiper *et al.* 2006). Little is known about their ecology in these areas other than that they seem to forage on rice kernels (Kuiper *et al.* 2006).

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Rice fields are considered a very important agricultural habitat for birds (Fasola & Ruíz 1996, Elphick & Oring 1998). In many cases rice fields are seen as substitutes for natural wetlands in places where drainage and other human developments have forced birds away from their original habitats (Elphick 2000, Lawler 2001, Tourenq *et al.* 2001). However, the intensification of rice farming involves changes in the management of rice paddies, with consequences for their use by birds (Maeda 2001, Elphick & Oring 2003). In some areas the lack of economic incentives and European Union directives have led farmers to abandon rice fields or change them to corn fields (GPPAA 2006), reducing the available habitat as a stopover resource for Godwits.

In Portuguese rice cultures, most fields are harvested in September and October, after which the stubble is left standing. Most fields are left unmanaged throughout the winter, with the water level changing with rainfall, although in some areas fields are drained in order to keep the straw dry, after which it is burned. From December onwards farmers start to plough the fields in preparation for the next sowing season which occurs in April. During this time water levels mostly fluctuate with rainfall. Thus, a mosaic of flooded, wet and dry fields in different stages of management is found when godwits arrive in Portugal in late December.

Information on the stopover ecology of Black-tailed Godwits is very limited, and a better understanding of their food and habitat preferences will allow an assessment of how rice farming practices affect the quality of their stopover habitat. The present study aims to explain the patterns of use of rice fields by Black-tailed Godwits as a function of food preferences, food availability and rice field management, thus providing important guidelines for the management of these areas for Black-tailed Godwit conservation.

METHODS

Study site

Fieldwork took place in a number of rice plantations around the estuaries of the Tejo ($38^{\circ}57'N$, $8^{\circ}54'W$) and Sado ($38^{\circ}24'N$, $8^{\circ}38'W$) rivers (Fig. 1), located near Lisboa along the central western coast of Portugal. These are two of the main rice production areas in Portugal, with significance in the context of southern Europe (Lains & Sousa 1998). Field surveys were performed during the Black-tailed Godwit stop-

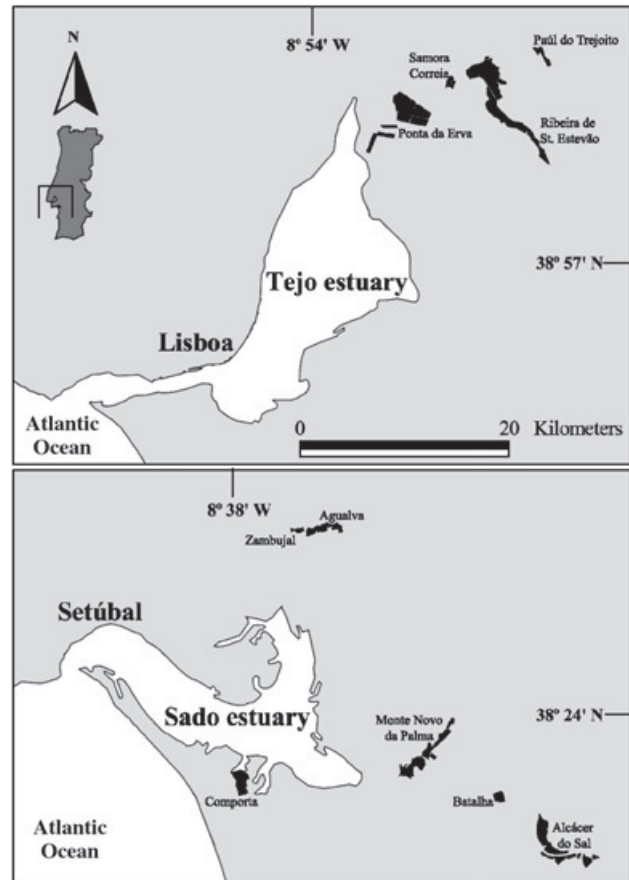


Figure 1. Map of the study areas, located around the estuaries of the Tejo and Sado rivers on the west coast of Portugal. The monitored rice field areas are shown in black.

over period in the area from December 2005 to February 2006 and from December 2006 to February 2007.

Habitat selection

In the course of the two winters, 120 randomly selected rice paddies were characterized according to type of straw management (standing stubble, ploughed fields and set-aside fields) and water level (flooded fields, water in ditches, wet soil, and dry fields) to evaluate habitat availability. The same paddies were studied in both years, and represented over 10% of the total rice cultivation area (280 out of 2547 ha) that was monitored for godwit presence. This habitat characterization was performed once every fortnight, thus yielding ten samples in each paddy, five in each year, from the second half of December to the second half of February.

Several times each week we surveyed all 2547 ha for

godwit flocks. Whenever a flock was detected, it was assigned to the rice paddy where it was found, which was also characterized as above. To determine if foraging Black-tailed Godwits used particular habitats selectively, we compared the proportion of godwit flocks observed in each habitat with the proportion of the respective habitats available each fortnight. Since proportions of habitat types always total 1 and are not interdependent (unit-sum constraint, Aitchison 1986), we used compositional analysis to examine our data. This method renders the proportions independent and approximately normally distributed by log-ratio transformation based on one of the proportions as denominator, after replacing zero values with 0.01 (Aebischer & Robertson 1992). Using multivariate analysis of variance and a suitable statistic (Wilk's lambda, Λ), it is then possible to assess whether log-ratio differences (utilized – available) differ significantly from 0 (random habitat use) over all the periods. Finally, a rank of the habitats can be composed, based on the relative use of each type, also taking into account when different ranks represent statistically significant differences in the relative utilization of the corresponding habitat types (Aitchison 1986, Aebischer & Robertson 1992, Aebischer *et al.* 1993, Tomé & Valkama 2001).

Food availability and diet

In 2006, a group of 48 rice paddies, representative of the different management and water level conditions, was sampled using a flat shovel that was able to cut through the hard roots in the soil. Each sample was a 10 × 10 cm square, with a depth of roughly 12 cm, to correspond with the maximum bill length of an adult Black-tailed Godwit (Cramp & Simmons 1983). In each paddy, four samples were collected at the beginning of the stopover period, in order to estimate food availability for godwits before they could have any significant depletion effect on the fields. The four samples from each paddy were averaged and data were log-transformed before further analysis. Additionally, on eight occasions we collected paired soil samples in paddies recently used by godwits and in a randomly selected paddy within 500 m of the first, but where no godwits were observed. The latter were paddies where no godwits had been seen until the sampling date and later observation showed that they had not been used at all during our study. Again, we collected four samples per paddy, which were averaged for analysis. All samples were sieved through a 1 mm mesh and all

invertebrates and seeds were identified under a stereomicroscope.

In fields that were not completely flooded, we were able to collect godwit faeces, which were stored in 70% ethanol until further analysis. These faeces were collected in paddies where very large groups of godwits had been foraging for several hours and so there was little chance of wrongly collecting faeces from other species, and each faeces was selected, based on size and appearance, to ensure no faeces of other species (e.g. gulls) were taken. A total of 79 individual faeces were sieved through a 63 µm mesh and examined for food remains under a stereomicroscope. For most items it was possible to identify individual prey species in the faeces, but this was not the case for oligochaete worms, which were identified by the presence of chaetae in the samples. This poses a problem when trying to determine the proportion of the diet represented by each food type. However, as the few samples where oligochaete chaetae were found had a very low number of chaetae (mean 34.2, range 5–66, $n = 5$), compared with the number of chaetae present in one oligochaete worm (mean 1078, range 624–1296, $n = 45$, Wroot 1985), we assumed only one worm in each faeces.

RESULTS

Habitat selection

As a consequence of farming activities and rainfall, the conditions in the rice fields varied over the course of the season. In both years we observed that the proportion of ploughed fields increased, as the farmers started preparing the rice paddies for the spring sowing, while the water level in the paddies changed in a more variable fashion, following the stochasticity of rain patterns (Fig. 2).

The habitat use by Black-tailed Godwits showed a rather clear pattern (Fig. 3). Of a total of 205 observed flocks (92 in the first winter, 113 in the second winter), most were seen in ploughed and flooded fields. With respect to field type, the godwits occurred more often than expected in ploughed fields, secondarily using set-aside fields, while avoiding the more common standing stubble (compositional analysis, $\Lambda = 0.21$, $P < 0.01$). With respect to water level in the rice paddies, the godwits used flooded fields more than would be expected if use were random, whereas all other water levels were used less than expected (compositional analysis, $\chi^2 = 0.04$, $P < 0.01$). This pattern was maintained in each of the two years.

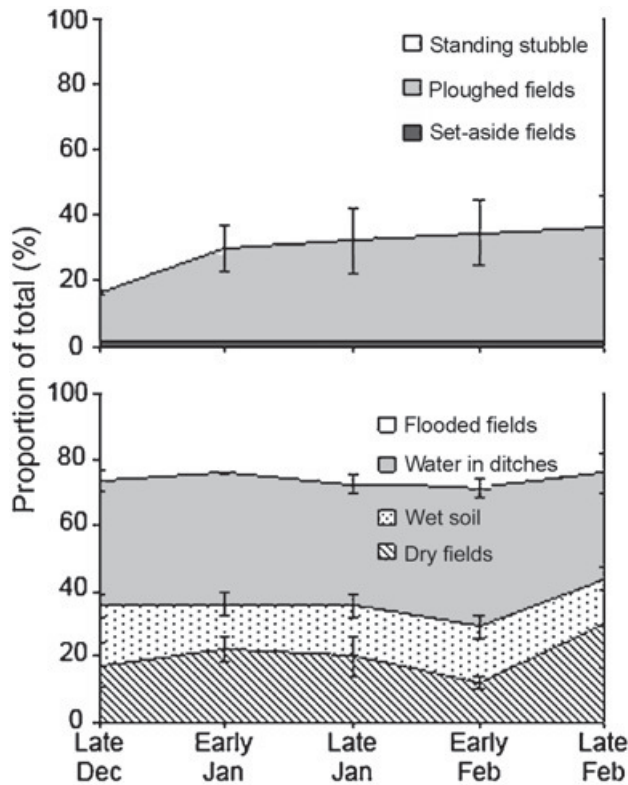


Figure 2. Variation in the availability of each management type and water level category during the stopover period ($n = 120$ per fortnight in each year). The sample period ranges from the second half of December to the second half of February and the percentages here present the average of the two years; error bars represent $\pm se$.

Food availability and diet

Fifty-eight of the 79 faecal samples contained noticeable food remains. Rice kernels, found in 78% of the samples, were the most common food item. Otherwise we found gastropods, oligochaete worms, dysticid insects and the Louisiana crayfish *Procambarus clarkii*, but all of these were present in fewer than 15% of the samples (Table 1). Overall, rice kernels represented 94% of the food items identified.

Given these dietary preferences, we were then able to determine in which types of rice fields food was more abundant. The abundance of rice kernels varied sharply between different rice paddies, from locations with no rice to paddies with over 10 000 kernels/m². This variation was related to the management type (two-way ANOVA, $F_{2,48} = 4.1$, $P < 0.01$) and water level of the paddies (two-way ANOVA, $F_{3,48} = 5.4$, $P < 0.01$) without significant interaction between the two factors (two-way ANOVA, $F_{6,48} = 0.77$, $P > 0.1$). With respect to management type, we found that ploughed fields had on average the highest abundances of rice kernels,

followed by standing stubble fields and finally the set-aside fields (Fig. 4). In relation to water levels, we found that flooded fields had by far the highest densities of rice kernels. However, post-hoc Tukey tests showed that in fields that were both flooded and ploughed, rice abundance was significantly higher than in any other, while ploughed fields with some water (wet fields or water in ditches) had significantly more rice than most other management types, even if flooded. Flooded fields of all management types tended to have more rice than fields with less water, although these differences were not always statistically significant. We found no statistically significant differences in the abundances of other food items between different management types and water levels.

These results suggest that the observed habitat selection is likely to be related to the abundance of rice kernels, the main food item for Black-tailed Godwits during stopover. To further investigate this hypothesis, on eight occasions we collected paired soil samples in a field where godwits were seen foraging and in a random rice field within 500 m of the first, where no godwits were observed. Again, we found that rice abundance was significantly higher (Wilcoxon matched pairs test, $z = 2.52$, $P < 0.05$, $n = 8$) in the paddies where Black-tailed Godwits were foraging (Fig. 5).

DISCUSSION

Habitat selection

We found foraging Black-tailed Godwits to be very selective with respect to the type of rice field used. They clearly use flooded and ploughed fields more often than expected, rather than dryer or unploughed land, although the latter are the most common rice field conditions. Their use of fields with a higher abundance of the main food item, rice kernels, confirms the common pattern that during the non-breeding period habitat selection is primarily driven by food availability (Nehls & Tiedemann 1993, van Gils *et al.* 2004, Lourenço *et al.* 2005, Piersma 2006).

Confirming suggestions by Beintema *et al.* (1995) and Kuiper *et al.* (2006), our faecal analysis showed that the main food items during the stopover period are rice kernels. In fact, rice seeds represented over 90% of the food items found in the faeces. Other food items, including gastropods, oligochaetes and arthropods, seem to be marginal in the diet. Black-tailed Godwits wintering in rice fields in Senegal also fed on rice (Trecu 1994), but Black-tailed Godwits are mostly

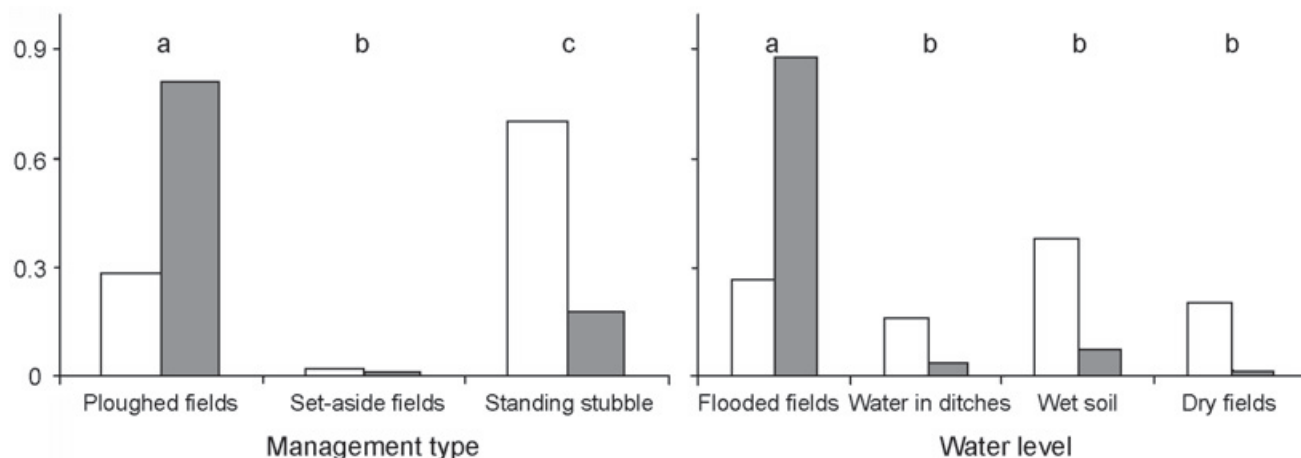


Figure 3. Habitat selection of Black-tailed Godwits in the rice fields. The white bars represent the proportion of rice paddies ($n = 120$ per fortnight in each year) assigned to each management type or water level category; the grey bars indicate the proportion of godwit flocks ($n = 205$) observed in each category. Note that the godwit flocks were detected in all of the study areas and not only in the subsample of 120 paddies used to measure habitat availability. For each variable, godwit preference decreases from left to right; different letters indicate significant differences in the compositional analysis.

carnivorous in habitats such as mudflats (Moreira 1996), salt pans (Perez-Hurtado *et al.* 1997) and grasslands (Beintema *et al.* 1995). However, herbivorous foraging has been described for a closely related species, the Hudsonian Godwit *Limosa haemastica* (Alexander *et al.* 1996).

Correlates of food availability

Rice grains are accidentally spilled in the fields during the harvest, in September and October, staying in the fields during the following autumn, until the arrival of the godwits in late December and January. The water level and management type affect the abundance of rice kernels in distinct ways. To some extent, flooded fields can cause loss of rice seeds due to decomposition, a factor that has been shown to be of great importance in the Mississippi alluvial valley (Stafford *et al.* 2006). On the other hand, dry fields attract granivorous

passerines (Elphick 2004), which gather in flocks that quickly remove the spilled rice, leaving hardly any seeds in the soil by the time the godwits arrive (pers. obs.). This phenomenon also becomes clear in fields that become dry during the winter, due to drainage or lack of rainfall. In such fields, large groups of sparrows (*Passer* spp.) and finches (*Carduelis* spp.) were seen gathering to eat the rice that became available. Another source of depletion in dryer rice fields is the rodents that feed on rice seeds and frequently become a pest to farmers (Rabiu & Rose 2004, Brown & Tuan 2005). Despite possible losses to decomposition, foraging by small granivores is likely to explain our finding that flooded fields have very much higher rice kernel abundances than fields with lower water levels. Thus, only fields that are flooded, or at least partially flooded throughout autumn and winter, are likely to be of interest to foraging godwits.

With respect to management type, the finding that ploughed fields have a much greater abundance of rice kernels than unploughed fields seems to explain the observed godwit habitat selection. Although we have no quantitative proof, we speculate that the greater abundance of rice in ploughed fields is caused by the fact that much of the spilled grain is buried in the soil by the wheels of the harvesting machines, thus becoming inaccessible to the birds (and conversely inaccessible to our sampling) until the time when the fields are ploughed and the deeper soil layers are brought to the surface again by the tractors. Apparently, northward migrating Black-tailed Godwits find their ideal foraging habitat in rice fields based on

Table 1. Diet of Black-tailed Godwits during migratory stopover in Portuguese rice fields.

	Presence in faeces	Proportion of diet
Rice kernels	0.78	0.94
Gastropoda	0.14	0.04
Oligochaeta	0.09	0.01
Distycidae	0.05	0.01
<i>Procambarus clarkii</i>	0.03	0.00

'Presence in faeces' is the proportion of faeces ($n = 58$) in which each food type was found. 'Proportion of diet' is the proportion of the total number of identified food items ($n = 453$) represented by each food type.

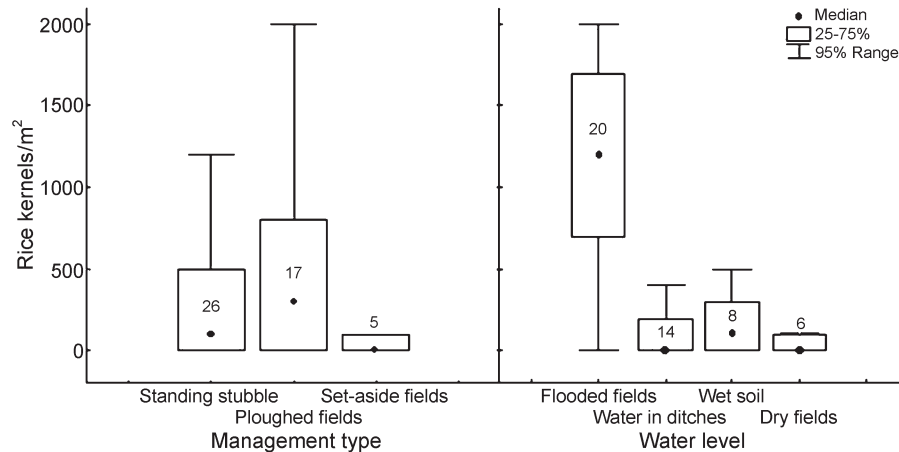


Figure 4. Rice kernel abundance in the different rice field types. Both management type and water level were found to have a significant effect on rice abundance. Analysis is based on 192 samples collected in 48 different rice fields. The number of fields sampled in each category is presented.

the amount of rice and, probably, on the depletive effect of other granivores on rice abundances. Different farming practices and water levels have an effect on these competitors, determining where the rice is during and after godwit arrival. The question remains whether the waterbirds that are common in rice fields (Fasola & Ruíz 1996, Elphick & Oring 1998, Tourenq *et al.* 2001) could possibly reduce the food available. Of the species concerned (Northern Lapwings *Vanellus vanellus*,

White Storks *Ciconia ciconia*, Black-headed Gulls *Larus ridibundus*, Little Egrets *Egretta garzetta* and Common Snipe *Gallinago gallinago*, P.M. Lourenço unpubl. data), White Storks and Little Egrets forage extensively on the abundant Louisiana crayfish (Correia 2001, Marques & Vicente 1999) and the others are also known to be primarily carnivores (Lajmanovich & Beltzer 1995, Moreira 1995, Tsachalidis & Goutner 2002, Holland *et al.* 2006). Our own study proves that typically carnivorous species can use rice grain as a seasonal food source; however, as all other bird species were present in very much lower densities, it is unlikely that they would have a depletive effect on the food available for godwits.

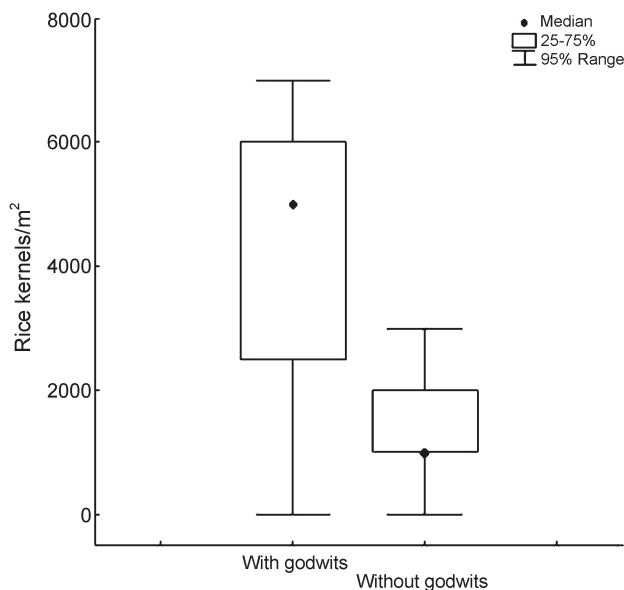


Figure 5. Differences in rice abundance between fields used by foraging godwits and other random fields. The paddies used by foraging flocks had significantly greater abundance of rice kernels. Analysis is based on 64 samples collected in eight pairs of rice fields.

Guidelines for modern godwit-friendly rice farming

Food abundance and the activity of granivorous competitors probably determine where godwits can find food. However, as in other man-made agricultural habitats, the conditions encountered by Black-tailed Godwits upon return from west Africa will depend on the decisions made by farmers and environmental managers. The modernization of rice farming frequently involves better drainage systems that allow farmers to keep their fields dry during winter (Shuford *et al.* 1998, Elphick & Oring 2003). Farmers can then burn the stubble, quickly removing plant remains. However, as the activity of foraging birds in flooded fields accelerates decomposition, eliminating plant residues (Bird *et al.* 2000), we can envisage a management scenario that does not cause air pollution through burning and that is of benefit to both farmers and wild

birds (Badarinath *et al.* 2006). Instead of draining the fields, the blocking of field drainage to help retain rain-water (a management method suggested for rice fields in North America, Elphick & Oring 2003, Manley *et al.* 2005) is likely to also be beneficial in southwest Europe, especially as rainfall is likely to decrease in the future (see below).

Ploughing is another way in which farmers influence habitat quality for Black-tailed Godwits. The timing of ploughing is crucial, as the birds stay in the area for a limited period of time. If farmers do not plough their fields until March, the godwits are already on their way to the breeding grounds and thus miss that potential food source. Currently, there are no guidelines for rice farmers, who usually have other occupations during the winter and plough the fields when they have free time. Also, in more modern, large-scale rice cultivations, the fields are usually only ploughed later, shortly before sowing, and after the Black-tailed Godwits have departed from Portugal (pers. obs.).

The implementation of more efficient harvesting methods can reduce the amount of spilled rice seeds, diminishing the rice available for godwits, but it is hard

to estimate the extent of this impact. More serious is the substitution of rice by other crops, such as maize, causing a serious reduction of available habitat for northward migrating Black-tailed Godwits.

Finally, there is another way in which human activities might affect the stopover ecology of Black-tailed Godwits in Portugal. With increasing evidence of human-caused global climate change (Crowley 2000), current climatic models for the Iberian Peninsula predict a decrease in rainfall (Goodess & Jones 2002). As rainfall determines the amount of water in many rice fields, especially the more traditional fields where most godwits are found, climatic changes could reduce the availability of high quality foraging habitat.

Since the ancient natural wetlands where godwits used to forage are now mostly gone (Kuiper *et al.* 2006), it is essential that rice fields are maintained in a way that will allow Black-tailed Godwits to find food there. For this purpose we suggest that fields should be kept flooded throughout the autumn and winter, at least part of the ploughing ought to take place between December and February (Fig. 6), and the substitution of rice by other crops should be avoided. As most rice

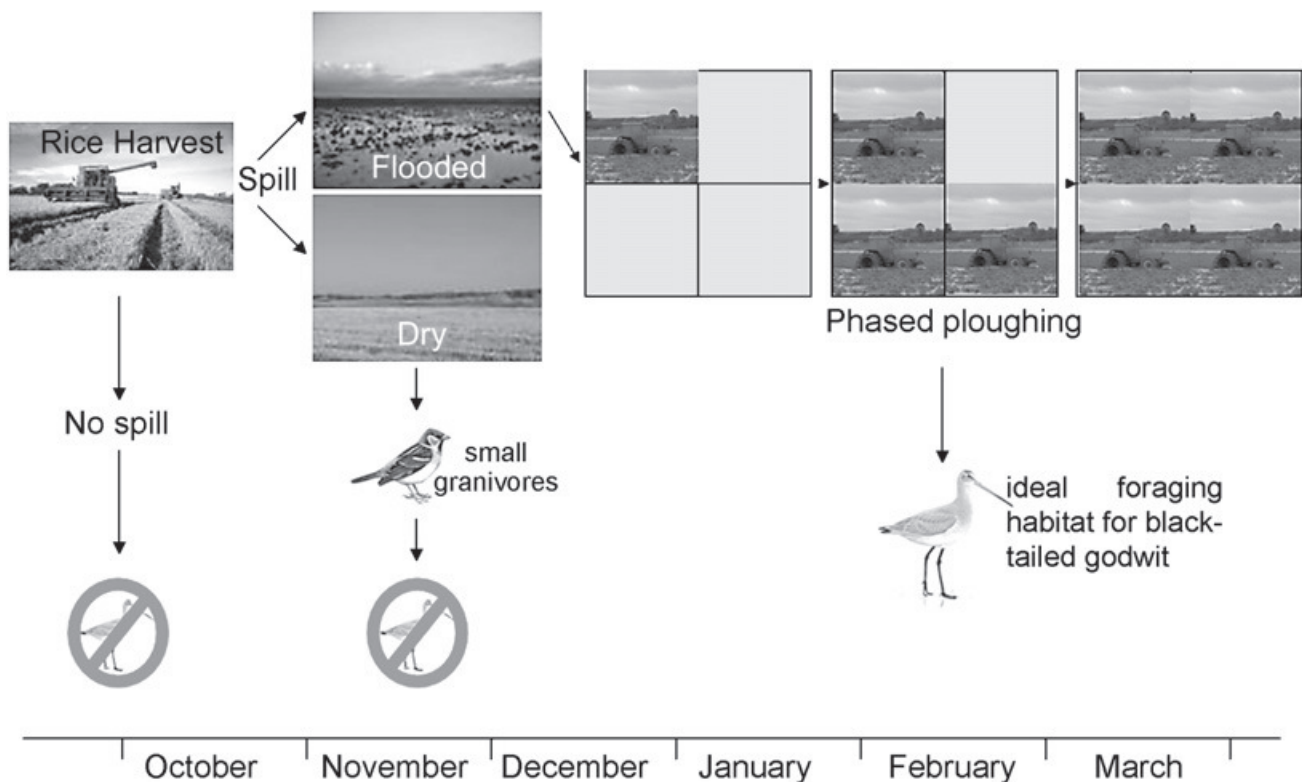


Figure 6. Schematic illustration of how the management of rice fields can determine the quality of foraging habitat for Black-tailed Godwits. Early in the season, the presence of spilled rice and the flooding of the fields are essential for later godwit presence. During the stopover period, phased ploughing of the fields is likely to create ideal conditions for foraging godwits by ensuring a continuous supply of fields in which grain is newly available.

farming in the lower basins of the Tejo and Sado rivers is controlled by farming co-operatives, some of which are closely associated with Portuguese government institutions, we encourage the Portuguese ministries of Agriculture and Environment to support the implementation of a set of environment-friendly farming practices in the rice fields, following the guidelines summarized in Fig. 6. In addition, as rice farming is highly dependent on EU funding (GPPAA 2006), European financial incentives could be the best way of ensuring the willingness of farmers to manage their rice fields in a godwit-friendly fashion.

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